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Assessing medium range weather forecast and economic impact of agro advisories on wheat in Jalandhar, Punjab

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सार – यह अध्ययन पंजाब के जालंधर जिले में मध्यम अवधि मौसम पूर्वानुमान (एमआरडब्ल्यूएफ) की उपयोगिता और रबी ऋतु 2020 - 21 के दौरान गेहूं पर इसके आर्थिक प्रभाव का विश्लेषण करने के लिए किया गया। इस संदर्भ में, वास्तविक आंकड़ों पर वर्षा के लिए मध्यम अवधि मौसम पूर्वानुमान (एमआरडब्ल्यूएफ) का गुणात्मक और मात्रात्मक विश्लेषण किया गया था। गेहूं की फसल के लिए एमआरडब्ल्यूएफ के आधार पर कृषि मौसम परामर्श सेवाओं (एएएस) का आर्थिक प्रभाव तैयार किया गया। परिणामों से पता चला कि मॉनसून के बाद, सर्दियों और रबी के दौरान वर्षा की उपयोगिता 80 प्रतिशत से अधिक थी। इसके अलावा,एएएस को अपनाने के कारण गेहूं की फसल के लिए पूंजीगत लाभ के संदर्भ में आर्थिक प्रभाव एएएस को अपनाने और नही अपनाने की तुलना में रुपये 5288 से रु. 7245 के बीच रहा प्रभावी कृषि - खेती के लिए इस उपयोगी उपकरण के प्रति किसान समुदाय का विश्वास बढ़ गया है।

ABSTRACT. The study was conducted to analyze the usability of Medium Range Weather Forecast (MRWF) in Jalandhar district of Punjab and its economic impact on wheat during Rabi season 2020-21. In this context, qualitative and quantitative analysis of Medium Range Weather Forecast (MRWF) was done for the rainfall over the actual data. The economic impact of Agromet Advisory Services (AAS), prepared on the basis of MRWF for wheat crop. The results revealed that the usability of rainfall was more than 80 per cent during post-monsoon, winter and Rabi. Further, the economic impact in terms of capital gain varied from Rs. 5288 to Rs. 7245 in the adopted AAS over non- adopted AAS for wheat crop due to adoption of AAS and thus, enhancing the faith of farmer community to adopt this useful tool for effective agri-farming operations.

Key words– AAS, Rainfall, Skill score, Usability, Economic impact

1. Introduction

Agriculture in India depends on weather and climatic conditions. Weather through various atmospheric factors plays a significant role in reaping good agricultural output (Bal and Minhas, 2017). Variable and uncertain weather is a pervasive fact that farmers have to cope up with it and this has bearing on the livelihoods of farmers. Lack of timely and reliable agro-meteorological information is a serious limitation for effective farm planning operations (Rao and Manikandan, 2008). Weather forecasts are essential for taking decisions regarding crop choice, crop variety, sowing harvesting dates and judicial management of agricultural operations such as field preparations, ploughing, irrigation, scheduling and application of fertilizers, pesticide, herbicide and harvesting.

The emerging capacity to provide timely and skillful weather forecasts offer the potentiality to reduce vulnerability and losses incurred due to vagaries of different weather hazards (Hansen, 2002). Thus, the AAS set up exhibits a multi-institutional and multi disciplinary synergy to render an operational service for use of the farming community. The Medium Range Weather Forecast (MRWF) based agro advisories are not only useful for efficient crop production management of farm inputs but also leads to precise impact assessment (Gadgil, 1987). Majumder and Kumar (2019) showed that the net income and profits of the farmers have enhanced significantly by avoiding the bad effect of the climate and weather aberrations with the judicious use of natural resources. Rathore *et al*. (2003) discussed the weather forecasting scheme operational at National Centre for MRWF for issuing location specific weather forecast three to five days in advance.

In general, it is very difficult to assess the economic benefit of any advisory service given to adopt necessary measures against catastrophes or life-threatening situations; however, it is possible to assess the economic benefit of the agro-meteorological services (Nicholls, 1996). This can be achieved if the scientific methods to be used for weather-based advisories have a direct relationship with the traditional knowledge of the farmers (Patt and Gwata, 2002). From a farmer's perspective, the forecast value increases if the weather and climate forecasts are capable of influencing their decisions on key farm management operations (Everingham *et al*., 2002; Ingram *et al*., 2002). Thus, the paper aims to study forecast reliability for the first time and justify the importance of agro-advisories by District Agromet Unit (DAMU) to develop faith in the AAS for achieving sustained agriculture.

2. Materials and methods

2.1. *Location of the study*

The study was conducted at Krishi Vigyan Kendra Nurmahal (Jalandhar). The geographical location of Jalandhar is 31°19'32" N 75°34'75" E. It is categorized as central plain zone of Punjab, India. It lies on 242 m above sea level. In this study, we obtained observed rainfall data for the year 2020-21 from Automatic Weather Station, Krishi Vigyan Kendra Nurmahal (Jalandhar) and forecasted rainfall data from India Meteorological Department (IMD).

2.2. *Verification of Medium Range Weather Forecast*

The verification of MRWF was done through different standard indices and statistically parameters like root mean square error (RMSE). Seasonal analysis of the forecast was verified on the basis of observed and forecasted rainfall data during 2020-21 for two seasons as standards of IMD *viz*. post-monsoon (October-January) and winter season (February-March) and one crop seasons *i.e*. *Rabi.* It is verified on the basis of contingency table which shows the frequency of "YES" or "NO". The four combinations of forecast and observed dichotomy, known as the joint distribution, are:

(*i*) YY (Hit)- Rainfall was forecasted and observed

TABLE 1

Simple success of rainfall forecast for Jalandhar

Seasons	Post-monsoon (Oct-Jan)	Winter (Feb-Mar)	Rabi (Nov-Apr)
YY (Days)	5	1	7
YN (Days)	4	5	8
NY (Days)	3	2	9
NN (Days)	111	51	157

(*ii*) NY (Miss)-Rainfall was not forecasted but observed

(*iii*) YN (False alarm)- Rainfall was forecasted but not observed

(*iv*) NN (Correct negative)- Rainfall was neither forecasted nor observed

2.3. *Forecast accuracy*

2.3.1. *Simple success probability analysis*

The qualitative analysis of medium range weather forecast was simply carried out on the basis of "YES" or "NO" (Table 1).

The ratio score (Kothiyal, 2017), HSS score, Bias score, FAR, Probability of Detection and threat score (Majumder *et al*., 2019) were calculated to test the weather forecast for rainfall during 2017-18. These scores are explained as below:

Ratio Score

$$\text{Ratio score} = \frac{YY + NN}{YY + YN + NY + NN} \tag{1}$$

Heidke skill Score

$$\text{HSSscore} = \frac{2(YYNN - YNNY)}{[(YY + NY)(NY + NN) + (YY + YN)(YN + NN)]} \tag{2}$$

Bias score (frequency bias)

$$\text{Bias} = \frac{(\text{hits} + \text{falsealarms})}{\text{hits} + \text{misses}} \tag{3}$$

TABLE 2

Critical values of error structure for usability analysis of MRWF

Usability	Rainfall (mm)	
	(≤10mm)	(>10mm)
Correct	Diff ≤ 0.2mm	Diff ≤ 2% of the observed
Usable	0.2 mm < Diff ≤ 2.0mm	0.2 mm < Diff ≤ 20% of the observed
Unusable	Diff > 2.0mm	Diff > 20% of the observed

False Alarm Ratio

$$\text{FAR} = \frac{(\text{false alarm})}{(\text{hits} + \text{false alarms})} \quad (4)$$

Probability of Detection (hit rate) - POD is an important component of Relative Operating Characteristics (ROC) used for probabilistic forecast. Its values range from 0 to 1 with 1 determining the perfect score.

$$\text{POD} = \frac{(\text{hits})}{(\text{hits} + \text{misses})} \quad (5)$$

Threat score (critical success index only)

$$\text{TS} = \frac{(\text{hits})}{(\text{hits} + \text{misses} + \text{false alarms})} \quad (6)$$

2.3.2. *Quantitative analysis of medium range weather forecast*

The quantitative analysis was conducted as per the critical values for error structure which was – 0 (No rain), 1-10 mm and >10 mm of rainfall.

2.3.3. *Usability analysis of medium range weather forecast*

Usability of forecasted rainfall was analysed using the critical values of rainfall as shown in Table 2.

2.4. *Root Mean Square Error (RMSE) between observed and forecasted rainfall*

We calculated the RMSE to find out the absolute error between observed and forecasted rainfall of Jalandhar using the following formula:

$$\text{RMSE} = \sqrt{\frac{\sum(F_i - O_i)}{n}}$$

where, F_i = Forecasted values

O_i = Observed values

n = Number of observations

2.5. *Economic impact analysis*

To analyse the economic impact of AAS on wheat, this study was conducted at Farm, Krishi Vigyan Kendra, Nurmahal (Jalandhar) by taking two major factors *viz.* Date of sowing (15th November and 5th December 2019-20) and Agromet Advisory Services (AAS and Non-AAS), where AAS is adoption and Non-AAS is non adoption of Agromet Advisory Services. The crop was sown in Randomized Complete Block Design in 0.5 acre plot each by following all the package and practices of wheat. The yield and yield attributes (effective tillers, number of ears per plant, number of grains per ear, test weight (g), grain yield (q) and biomass yield (q) of the wheat were recorded and were analysed using factorial Randomized Block design in CPCS package 1 (Cheema and Singh, 1991).

Economic analytical tool: This includes the detailed analysis of costs and returns.

Total input: It includes all the cash and kind expenses *i.e* seed price, fertilizer, micronutrient, herbicide, pesticide, human labour, machine labour and irrigation. Total output: The quantity of product produced from different crops taken as the total output. When the output is multiplied by its price then it is the output value. Net income: Net income is the difference between total income and total cost of cultivation. It was calculated as:

Net income = Gross income – Total expenses

Cost of production per hectare (Rs/acre): It refers to total input cost (in Rupees) divided by total area (in hectare). Benefit: Cost ratio: The benefit: cost ratio was computed by applying formula as follows (Singh and Gangwar, 2010)

$$\text{Benefit : cost ratio} = \frac{\text{Gross returns (Rs./ha)}}{\text{Total Cost of cultivation (Rs./ha)}}$$

The primary objective of the agro advisory services is to guide the farmers regarding the actual and forecasted weather and its effects on the day-to-day farm operations. The Agromet advisories prepared based on the predicted weather (Table 3) and were followed in AAS and not followed in non-AAS plots. Cost of input as well output as per adopted vs non-adopted agromet advisories were calculated by using the prevailing cost of inputs like seed,

TABLE 3

Agromet Advisories prepared and followed along with economic benefit

Date and amount of rainfall forecast	Advisory given and followed 4 days prior	Economic benefit
12 December - 6.0 mm 13 December - 1.0mm	Farmers are advised to skip the irrigation	One irrigation
3 January - 4.0 mm, 4 January - 15.0 mm 5 January - 25.0 mm 6 January - 9.0 mm 7 January – 5.0 mm	Farmers are advised not to irrigate the crop. Also spraying of pesticides/fungicides should be avoided	Spray of fungicide and one irrigation
24 January – 3.0 mm	Farmers are advised to do farm operation (irrigation, spray of pesticides/fungicides) according the weather forecast	Spray of pesticides/fungicide and one irrigation
13 March – 14.0 mm	Farmers are advised to skip the irrigation	One irrigation

TABLE 4

Seasonal rainfall forecast trends for Jalandhar

Seasons	Ratio score	HSS Score	Bias Score	False Alarm Ratio (FAR)	Probability of Detection	Threat Score
Post-monsoon (Oct-Jan)	94.3	0.56	1.13	0.44	0.63	0.42
Winter (Feb-Mar)	88.1	0.17	2.00	0.83	0.33	0.13
Rabi (Nov-Apr)	90.6	0.40	0.94	0.53	0.44	0.29

manures and fertilizers, insecticides/herbicides, labour incurred from land preparation to harvesting of the wheat. Further, the gross return of wheat was calculated by multiplying the yield into its selling price.

3. Results and discussion

3.1. *Verification and analysis of medium range weather forecast*

A five day medium range weather forecast received from Meteorological Centre, Chandigarh and IMD (Agrimet), Pune on every Tuesday and Friday of the week was used. The yearly data related to weather forecast was grouped in 3 distinct seasons, *i.e*., post-monsoon, winter and *Rabi* for analysis and verification. Both qualitative and quantitative verification analysis of only rainfall data was carried out being the most important parameters and concerning criteria for crop establishment using skill score and critical values for error structure. The root mean square error (RMSE) parameters were used for all the three seasons during the study period to assess or judge the reliability of the forecasted data as discussed below.

3.1.1. *Skill score analysis of medium range weather forecast for Jalandhar*

The skill score analysis of medium range weather forecast based on ratio score and HSS score during 2020-21 is revealed in Table 4. The average ratio score during 2020-21 was 94.3, 88.1 and 90.6; whereas the HSS score was 0.56, 0.17 and 0.40, respectively for post-monsoon, winter and *Rabi* season. The highest ratio score (94.3%) and HSS score (0.56) was obtained during the post-monsoon season showing the most skillful forecast of rainfall. The values of indices clearly showed that there was a better occupancy of forecast during the post-monsoon season. The results obtained were in agreement with the finding of Singh and Pal (2018); Vashisht *et al*. (2008); Navneet and Singh (2019); who found that the ratio score during post-monsoon was comparatively higher to other seasons. The FAR was lowest for post -

TABLE 5

Usability analysis and RMSE of rainfall forecast for Jalandhar

Seasons/Usability (%)	Correct (%)	Usable (%)	Unusable (%)	RMSE (mm)
Post-monsoon (Oct-Jan)	90	3	7	0.45
Winter (Feb-Mar)	85	10	5	0.48
Rabi (Nov-Apr)	86	6	8	0.32

TABLE 6

Yield and yield attributes of wheat during Rabi 2020-21 at Jalandhar

Treatments	Effective tillers/m^2	Ears/Plant	Grains no./ear	Test weight	Grain yield	Biomass yield
Dates of sowing (DOS)						
15th November	170	12	39	40.1	19.99	39.9
5th December	168	9	21	31.8	19.2	38.4
CD (0.05)	NS	2.2	1.7	1.8	NS	NS
Agromet Advisory Services (AAS)						
Adopted (T1)	169	11	31	33.5	21.1	42.1
Non-adopted (T2)	168	10	29	30	18.1	36.2
CD (0.05)	NS	NS	1.7	1.8	0.8	1.7
Interaction (DOS × AAS)	NS	NS	2.5	2.6	1.2	2.5

monsoon (0.44) and highest for winter season (0.88). Similarly Probability of Detection was lowest, *i.e.*, 0.33 for winter season and highest for post-monsoon season as 0.63.

Besides, the value of threat score was also higher for the post-monsoon season (42%). During winter and *Rabi* season, its value was 13 and 29% respectively. The lower value of threat score during winter signifies that the rainfall forecast was not in line with the observed rainfall. Majumder *et al.* (2020) also reported the lower values of threat score during winters in Malda, West Bengal.

3.1.2. *Usability analysis of Medium Range Weather Forecast for Jalandhar*

The usability analysis of rainfall forecast over the observed revealed the average forecast was successful by 90, 85 and 86% for post-monsoon, winter and *Rabi* season, respectively (Table 5). Similar results were found *via* studies of Chauhan *et al.* (2008), Rana *et al*. (2013) which revealed that the rainfall forecast was highly reliable during post-monsoon, winter and *Rabi* season.

The comparative study of RMSE between observed and forecasted rainfall (Table 5) revealed the lowest average RMSE was observed for *Rabi* (0.32 mm) representing the very low error and difference between observed and forecasted values. The highest RMSE was observed for winter season (0.48 mm). The results were in agreement with the findings of Singh and Pal (2018); Rana *et al.* (2013) and Das Desai (2018).

3.2. *Effect of medium range weather forecast on wheat crop*

3.2.1. *Yield and yield attributes*

The number of effective tillers was statistically at par in 1st date of sowing (15th November) and 2nd date of sowing (5th December) (Table 6) whereas number of ears (spikes) was significantly higher in 1st date of sowing (12) that the 2nd date of sowing (9) at $p = 0.05$. Similarly, the number of effective tillers and number of ears per plant were statistically at par in AAS adopted and AAS non-adopted. The number of grains per ear was significantly higher in 1st date of sowing (39) that the 2nd date of

TABLE 7

Comparative analysis of cost of cultivation in wheat during Rabi 2020-21 at Jalandhar

Inspects for the crop	15th November, 2020-21				5th December, 2020-21			
	AAS farmers		Non-AAS farmers		AAS farmers		Non-AAS farmers	
	Quantity	Cost/acre	Quantity	Cost/acre	Quantity	Cost/acre	Quantity	Cost/acre
Seed	40	1200	40	1200	40	1200	40	1200
Seed treatment	150	50	300	100	150	50	300	100
Fertilizer								
Urea	110	595	110	595	110	595	110	595
DAP	55	1238	55	1238	55	1238	70	1575
Potash			20	392			20	392
Pesticide/Herbicides								
Stomp 30 EC (ml)	1000	500	2000	1000	1000	500	2000	1000
Tilt 25 EC (ml)	200	210	400	420	200	210	400	420
Actara 25 WG (g)	-	-	40	200	-	-	40	200
Gypsum	-	-	100	600	-	-	100	600
Human labour	14	4928	17	5984	14	4928	17	5984
Machine labour	7	2500	7	2500	7	2500	7	2500
Irrigation	3	180	5	300	3	180	5	300
Harvesting	-	3100	-	3100	-	3100	-	3100
Total cost (Sum of all above)	-	14501	-	16437	-	14501	-	16774
Gross return	21.1	37980	19.9	35820	19.2	34560	18.1	30780
Net Return (Total VOP-Total cost)	-	23479	-	19383	-	20059	-	14006
B:C	-	1:2.6	-	1:2.2	-	1:2.4	-	1:1.8

sowing (36) and in AAS adopted (40) that AAs non-adopted (34) at p = 0.05.

The test weight, was also significantly higher in 1st date of sowing (40.1g), than 2nd date of sowing (33.5g). However, grain yield and biomass yield (20.9q/acre and 39.9q/acre, respectively) were statistically at par with 2nd date of sowing (19.2q/acre and 38.4q/acre, respectively). While, the test weight, grain yield, biomass yield was significantly higher in AAS adopted (33.5 g, 21.1 q/acre, 42.1 q/acre, respectively) than AAS non-adopted (30.0 g, 18.1 q/acre and 36.2 q/acre, respectively). Similar results were shown by Singh and Pal (2018).

3.2.2. *Economic impact assessment of AAS on wheat production*

The comparative analysis of the cultivation cost of wheat on the basis of adopted AAS and non-adopted AAS for the two dates of sowing *viz*., 15th November and 5th December (Table 7). The total cost of cultivation was Rs 16101 and Rs 19229 per acre for adopted AAS and non-adopted AAS, respectively for 15th November sowing. However, the cost of cultivation was Rs 16101 and Rs 19566 for adopted AAS and non-adopted AAS, respectively for 5th December sowing. The timely sown wheat (15th November) yield 21.1 q/acre for adopted AAS and 19.9 q/acre for non-adopted AAS, hence the gross return was Rs. 37980 and Rs. 35820 for adopted AAS and non-adopted AAS, respectively. On contrary, the late sown wheat (5th December) yield 19.2 q/acre for adopted AAS and 18.1 q/acre for non-adopted AAS, hence the gross return was Rs.34560 and Rs.30780 for adopted AAS and non-adopted AAS, respectively.

The net profit per acre was higher in adopted AAS for both dates of sowing. It was Rs. 23479 per acre for 15th November sowing under adopted AAS compared to the Rs. 19383 under non-adopted AAS. Under 5th December sown wheat, the net profit was Rs. 20059 and Rs. 14006 for adopted and non-adopted AAS, respectively. Thus, making the difference of Rs. 4096 and Rs. 6053 per acre between adopted and non-adopted AAS for 15th November and 5th December sown wheat, respectively. If farmers adopt the AAS, they can sustain their yields and get higher returns even under late sowing of the crop.

The results understandably revealed that the input cost is lower and the productivity is higher under adopted AAS compared to non-adopted AAS. Similar findings were also reported by Rajegowda *et al.* (2008), Chaudhari *et al.* (2010), Kushwha *et al.* (2010), Singh *et al.* (2020), Mummigatti *et al*. (2013) and Dupdal *et al*. (2020).

4. Conclusion

We conclude that the MRWF for rainfall issued by Meteorological Centre, Chandigarh is highly useful during post-monsoon and *Rabi* season and this can be used to facilitate the farmers to make broad decision on the crop management operations. The adopted AAS farm gives higher yield and net returns than non-adopted AAS due to the judicious and efficient use of inputs and following the AAS in the farming operations. This study can enable farmers to get maximum utility of AAS for sustaining agricultural productivity.

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